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INFORMATION CIRCULAR

LIGHTING PRACTICES IN COAL MINES OF THE UNITED STATES

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BY

A. B. HOOKER AND C. W. OWINGS

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

LIGHTING PRACTICES IN COAL MINES OF THE UNITED STATES 1/

By A. B. Hooker2/ and C. W. Owings3/

INTRODUCTION

Since man first mined underground, there has been need for adequate illumination; this need has never been fully supplied. At first, suitable lamps were not available. Gradually they have been developed, but along with that development the need for better and better lamps has continued owing to the following conditions and factors:

1. Increasing hazards from gas and dust ignitions.

2. The speeding of operations with mechanized mining, which necessitates greater visibility.

3. A demand that cleaner coal be loaded, which requires higher levels of illumination.

4. The cost of compensation for injuries that has created a demand for better illumination and safer lamps.

Use of better lamps has been retarded by:

1. Prejudice and resistance to change on the part of the workers in some districts.

2. The cost and upkeep of the lamps.

3. The present types of lamps, while a great improvement over the old lamps, do not entirely fulfill the requirements for a safe and efficient light for underground workers.

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Frequently, questions are asked about the present condition of underground lighting, what types of lamps are on the market, how many are in use, and how and where power lighting is used.

Answers to these questions has been obtained from the field engineers of the Safety Division of the Bureau, in all of the coal-mining districts of the United States, and from the laboratory and field experience of the engineers of the Central Experiment Station.

This paper presents the information obtained, describes the attitude of the coal-mining States toward mine lighting, as expressed in their coal-mine regulations, and suggests various ways to supply the need for better lighting underground.

CONCLUSIONS

The information at hand shows the following general conditions relative to lighting in coal mines:

Every underground worker has his individual portable lamp; approximately 50 percent of these lamps are permissible electric cap lamps. Excepting flame safety lamps and a few miscellaneous electric mine lamps, all of the rest are open-flame carbide cap lamps.

Shaft bottoms and underground areas usually are electrically lighted from power circuits, and generally there are power lights along main haulageways and at track switches.

Few, if any, coal-mine working faces are flood-lighted from power mains, and there is not much demand for such lighting. This is due to (1) excessive cost of installing, maintaining, and extending the lighting equipment, (2) increased hazards of ignition, and (3) the fact that individual lamps are necessary anyway and that often the illumination given by such lamps is considered satisfactory.

Power flood-lighting in gassy coal mines is not always feasible; it would increase hazards at the face workings at least until such time as suitable lighting fixtures and wiring could be obtained. However, increased illumination could be obtained in every coal mine by doing the following:

1. Use the more modern designs of portable electric lamps and maintain them adequately. Electric mine-lamp manufacturers are constantly improving their product as to useful light output and maintenance service of rented lamps. Each operator should insist upon the best to be had in these respects.

2. Use a separate lighting circuit wherever incandescent lights are used, to avoid the wide fluctuations in voltage of the usual mine power circuit, and the very definite hazards usually met when current is obtained from the customary mine power line, especially the trolley system.

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3. Decrease glare where feasible. Usually glare is caused by exposure to direct filament light or a concentrated beam of light, such as is produced by a polished reflector. The eye, adjusted to the relatively low values of illumination underground, does not instantly readjust itself to a sudden increase in light, and momentary blindness follows. Glare always decreases visibility, and continued exposure to such abnormal differences in light causes excessive eye fatigue. Glare can be decreased by putting shades on the power lights or by recessing the lamps in the ribs or roof.

An effective way to reduce glare from haulageway lights is to hang small boards from the roof 3 or 4 feet away from each lamp in such a way that they will not interfere with the illumination of the floor, side walls, or roof, yet will shade the direct filament light from the eyes of anyone approaching along the entry or haulageway. Glare from electric cap lamps should be minimized by using only diffusing-type reflectors, especially where men work in groups.

4. Increase the reflectivity of the surrounding surfaces. Coal surfaces reflect only about 5 percent of light. Light is therefore lost in all directions by absorption. This loss can be reduced by suitably rock-dusting as much of the surrounding surfaces as is practicable.

5. Increase the visibility. Visibility in a coal mine is affected by the dustiness of the atmosphere and by the colors of the things observed. Coal dust, by cutting off and absorbing light, causes a double loss in that it acts to decrease both the light from the lamp to the surface observed and the light reflected back to the observer. Some operators run water pipes to the working faces and minimize the amount of dust in suspension by spraying during cutting and loading operations. Visibility also may be improved through the use of reflector buttons for signs and through painting tools and equipment such colors as will cause them to stand out from their surroundings.

6. Use special lamps for special purposes, such as (a) inspection lamps where long-range vision is desired, taking care to wear or carry the lamps in such a way as to avoid glare to others; (b) signal lamps on all moving trips of cars; (c) portable floodlights for auxiliary lighting wherever extra light is needed temporarily; and (d) animal lamps, so that each haulage animal is assured of unobstructed light.

Mine Safety Board Decision

Since 1928, the Bureau of Mines has officially recommended[4/] that in all coal mines the portable lamps for illumination be permissible electric mine lamps. This decision was based on the need to reduce the hazards of gas

4/ Mine Safety Board, Recommendations of the Bureau of Mines on Certain Questions of Safety; Decision 1, Relating to Miners Lamps in Coal Mines: Inf. Circ. 6091, Bureau of Mines, 1928, 12 pp.

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and dust ignitions and on the fact that better illumination and greater convenience in use are offered by electric safety lamps. The greater candlepower and general practicability of the later types of cap lamps and the greater variety and application of the special electric mine lamps justifies this decision to even a greater extent today than when it was made in 1928. Increased use of these lamps and more and better rock-dusting, white-washing, and allaying of dust should help materially to achieve more adequate lighting in coal mines.

TYPES OF LAMPS AVAILABLE

Three general types of lamps are available, namely, open-flame lamps, electric power lamps, and permissible lamps. The open-type lamps and the safety or permissible lamps have been developed especially for underground conditions, whereas, the power lighting equipment has been adopted more or less directly from general practice above ground.

Open Lamps

This classification includes oil lamps, candles, and carbide lamps; however, because of the demand for more light, carbide lamps have virtually superseded the others.

In response to the almost general demand of American miners, nearly all of the carbide lamps used in coal mines are the cap type.

The chief characteristics of the carbide cap lamps in use are (1) the weight is approximately 8 ounces, and (2) the burning time is 1 to 4 hours, depending upon the length of flame and the condition of the lamp. This means that each lamp requires refilling two to eight times per shift, possibly more if the water and carbide refills are not made at the same time. The flame fluctuates a great deal in brightness, owing to variation in size of flame, whipping of the flame by air currents, and movement of the user's head. If the reflector is clean, the light focus also fluctuates; if the reflector is blackened and dirty, there is no apparent change in light focus, but there is an appreciable decrease in amount of effective light.

Electric Power Lamps

Several general types of power lamps are available - (1) fixed incandescent lamps for general illumination at shaft bottoms and fresh-air entries and, to a slight extent, rooms; (2) semiportable lamps supplied with current through flexible extension cords for use in repair barns and for use in inspecting machinery and, to some extent, room and entry faces; (3) projector-type lamps for flood-lighting nongassy working faces and areas; and (4) explosion-proof headlights for use on locomotives and the larger track-type cutting and loading machines.

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All of these power lights are incandescent lamps, except a few locomotive headlights, which are arc lights, and vapor lamps used for special lighting in weighhouses.

Permissible Lamps

Under the Bureau's test schedules, permissible lamps are placed in four groups, namely, (1) flame safety lamps, (2) electric cap lamps, (3) miscellaneous lamps (portable electric mine lamps other than electric cap lamps), and (4) electric headlights.

1. Flame safety lamps, for use by men whose duties include testing for methane. - The Koehler and American Wolf lamps are the only permissible flame safety lamps in use in the United States. Each is available in four models - round-wick steel, flat-wick steel, round-wick aluminum, and flat-wick aluminum. All have double gauzes, a protecting bonnet, and are magnetically locked. All burn a special grade of distillate called "safety-lamp fuel."

The round-wick models can be obtained equipped with a bimetal unit to aid in detecting low percentages of methane.

2. Electric cap lamps. - The following five permissible electric cap lamps are on the active lists of the Bureau of Mines at present - Edison models H, J, and K and Wheat models Q and W. These lamps are described in Bulletin 332[5] and its supplement, Report of Investigations 3304[6]. The electric cap lamp, like the open-flame cap lamp, is attached to the hat or cap of the user, leaving his hands free; the headpiece, or light unit, being on the front of the cap, turns with the head to illuminate the thing that is being observed; but, unlike the open-flame lamp, its light is safely enclosed - it is not affected by air currents or movements of the head, and it does not affect the mine atmosphere. On the other hand, it does not indicate methane or oxygen deficiency, and this is a very definite objection to the use of this type of lighting underground.

3. Miscellaneous electric lamps. - This group includes several types, as follows:

a. Hand lamps are used principally by officials when walking and for short-range inspection service. Four permissible hand lamps - Edison models H and K, the Super-Wheat, and the Ecolite dry-cell-type lantern, are on the present active list. Very few permissible hand electric lamps are used in coal mining in the United States, except flashlights, and these ordinarily are to be used only for emergency or intermittent service.

5/ Ilsley, L. C., and Hooker, A. B., Permissible Electric Mine Lamps: Bull. 332, Bureau of Mines, 1930, 39 pp.

6/ Ilsley, L. C., and Hooker, A. B., Permissible Electric Mine Lamps: Report of Investigations 3304, Bureau of Mines 1936, 11 pp. (Supplement to Bull. 332.)

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b. Signal lamps are a rugged type of lamp to be hooked over the end or side of the last car of a mine trip to show the haulage crew that the trip of cars is complete and to indicate the location of the trip to those following. Five signal lamps - the Concordia "CEAG", the Edison Model E 2-cell lamp, the Edison Model F2 single-cell lamp, the Wheat lamp, and the Justrite (dry-cell) lamp are on the current permissible list.

c. Flashlights are used underground chiefly as auxiliary lights for inspection service where long-range vision is desired, or for emergency service at explosions or fires. Three flashlights - the Eveready insulated type, the "Megolite," and the "Tuffite" - can be had in both the 2-cell and 3-cell sizes.

d. Animal lamps give a light to horses and mules in haulage service underground; for this, the lamp is strapped to the collar of the animal in such a position as to throw a diffused beam of light along the pathway. Two animal lamps - the Edison Models E and K - are on the current permissible list. The Model K lamp is equipped with a switch by means of which the light can be extinguished when the animal is left standing.

e. Floodlights are specially designed to be set or hung in a working place to provide limited general illumination or extra illumination for special work.

Two lamps, the M.S.A. Models E or G and the Wheat Stevedore lamp, are on the current permissible list; these, however, are small units. The Stevedore lamp was designed for use in holds of coal-carrying ships, where dangerous quantities of coal or other explosive dust in the air may be encountered, but it is also suitable for mine use.

f. Inspection lamps are either of the cap-lamp or hand-lamp type equipped with polished reflectors to supply a concentrated light beam for long-range vision. Three lamps - the Edison model E, the Super-Wheat cap lamps, and the Wheat model S hand spotlight - are on the current Bureau of Mines permissible list.

4. Headlights. - Permissible headlights are provided on all permissible storage-battery locomotives and on practically all track and tractor types of permissible coal-cutting and loading equipment.

Locomotive headlights have polished reflectors that throw a concentrated beam along the haulageway. In general, headlights on cutting and loading machines are for short-range lighting; therefore, they may have either diffusing reflectors or none at all, as in the case of two-way lights.

Some of the machine headlights are so mounted that they act as floodlights to illuminate the face or work at hand; others are chiefly for lightin the machine itself or certain operating parts thereof.

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HOW THE LAMPS ARE USED

Open Lights

Few, if any, oil lamps are now used for lighting in coal mines; they have been replaced chiefly by carbide cap lamps, and the number ranges from 10 percent of all mine lamps used in Pennsylvania to virtually 100 percent in Georgia. Nearly 50 percent of all mine lamps in use in the United States are carbide cap lamps, but this percentage is being steadily reduced by the increasing use of permissible electric cap lamps in both coal and metal mines.

Mixed lights are used in some mines, such as those where electric cap lamps are on trial, where only certain employees are permitted to use the electric lamps, or where certain parts of the mine are supposed to be free of explosive gas and other parts to be afflicted with emission of explosive gas. Bureau of Mines engineers are much opposed to the use of mixed open and closed lights in any coal mine.

Power Lamps

Fixed power lights are used chiefly for lighting shaft bottoms and main haulageways in mines, but the installations differ greatly. Sometimes power is obtained from special circuits of 110 volts A.C., but more often it is from the D. C. trolley circuit, the lamps being connected either singly or two or more bulbs in series. In some mines the wiring is in conduit with condulet-type lamp outlets. In some installations there are no sockets and the wires are soldered to the bulb terminals; generally, however, the wiring has weather-proof insulation and is mounted on insulators, and the sockets are of the weather-proof porcelain type.

In general, no lamp shades are used; where used, they are usually homemade of either tin, board, or paper; the use of combustible shades is hazardous in the extreme.

The lamps are spaced as needed from 10 to 50 feet or more apart and usually are of 50 to 100 watts.

Haulageway lighting, except in shaft bottoms, is generally limited to one or two lights at each track switch, with possibly some single lights at intervals along the roof or at or close to the rib near the roof, the light generally being suspended from the roof over the track. In a few mines these lights are set in the rib or else the direct light is cut off by a board on each side of the fixture; however, the chief purpose of all haulageway lighting, except in the shaft bottom, is not so much to light the haulageway as to locate the track switches and to increase safety in their operation.

Power-type floodlights seldom are used for face lighting, to some extent because of doubts as to safety but chiefly because of the cost,

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including cost of installation, of extensions as the work progresses and of protection against damage by blasting and machine operations. Another reason is the hazard of gas or dust ignition because no adequate safety fixtures are available and there is not sufficient demand for them to justify their development; also, each worker should have his individual lamp irrespective of any special lighting.

Locomotives have headlights, either of the incandescent or arc type, with polished reflectors, that light the roadway in haulage and give warning of the presence of the locomotive. Some of these headlights have polished reflectors, some have diffusing reflectors, and some have the tilt-beam feature to reduce glare.

Some track and tractor-type cutting and loading machines have incandescent headlights. Although these contribute indirectly toward face lighting, they are not very satisfactory for this purpose.

Not much is done to increase illumination with the present lamps except at underground stations, shops, barns, etc., where the walls and ceiling are sometimes white-washed or painted white. However, illumination is improved indirectly at many mines by such safety practices as rock-dusting, which increases the reflectivity of the surrounding surfaces, and by sprinkling at the face workings to keep down dust, which otherwise would cut off and absorb an appreciable amount of light. Relatively few coal mines white-wash important haulage-entry surfaces as an aid to illumination.

REFLEX SIGNS

Increasing use is being made of reflector buttons as aids toward greater visibility; these buttons, therefore, are factors in mine lighting. They are to be had in several different colors, including red, green, amber, and crystal white.

In general, the reflex signs are made up of half-inch buttons set in wood to form the desired design. They are used to indicate danger, direction, safety stations and equipment, location of derails, switch throws, etc. Some of the signs are placed permanently, while others are placed temporarily where needed; for example, a marker for a crew is hung by the crew when it enters a parting or branch entry and is removed upon its return. Thus, its sign identifies the crew and indicates in which section it is working.

PERMISSIBLE LAMPS

Flame safety lamps are primarily gas detectors; they are used as lamps in mines only by those whose duties include testing mine atmospheres for methane and for oxygen deficiency, and then chiefly in those mines where the use of an auxiliary electric lamp is not permitted.

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Electric cap lamps. Approximately 50 percent of all portable mine lamps in the United States are permissible electric cap lamps. They are used in mines designated gassy and in some mines designated nongassy, where the chief reason for their use is efficiency.

Where used, nearly every underground worker, except the few that are not permitted to have both flame and electric safety lamps, carries an individual cap lamp irrespective of what other lighting there may be.

Hand lamps. In coal mines of the United States hand lamps are used only by visitors or mine officials, who are not properly equipped to wear a cap lamp.

Signal lamps. At least one State (West Virginia) requires the use of a signal lamp on the last car of each moving trip. The Pennsylvania Bituminous Regulation as recently revised requires that "the Superintendent shall provide signals approved by the Secretary of Mines to be carried on the last car of all trips pulled and on the first car of all trips pushed in the mines by locomotives of any kind." The signal usually required is a permissible electric signal lamp. Although several of the other States require some kind of marker, in general trip or signal lamps are not mentioned in the various State mining codes; however, many mines use them, and the use is increasing. Virtually all of the trip lamps in use are permissible electric signal lamps because they have been specially designed for the service and are relatively rugged and reliable.

Flashlights. The chief use of flashlights in coal mines is for auxiliary lighting in inspection service, for occasional use by visitors, and for use by fire bosses and shot firers as auxiliary to flame safety lamps where such employees are not permitted to carry electric cap lamps. Flashlights are also useful in emergency work in connection with mine explosions and fires.

Animal lamps. Animal lamps are not required by any of the States and are not used extensively, except by one company in Alabama. It is said that animals do not need lights; that if an animal has its own light it often will not stand unattended; that often the lamp is broken, especially against the manger at feeding time. However, where the lamps have been used consistently and with reasonable attention to their care, there has been a noticeable increase in the amount of work done per animal, a decrease in the number of injuries not only to animals but also to their attendants, and less haulage delay. The trend is toward greater use of permissible electric animal lamps.

Floodlights. The principal application of flood lighting in coal mines is in special or emergency construction and repair work where extra lighting is needed. Most of this lighting is done by power lamps supplied from the trolley circuit. Few or no portable electric floodlights are used in coal mines.

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STATE LAWS RELATIVE TO LIGHTING IN COAL MINES

Open Lights

The regulations of the several States relative to the use of open lights are quite different, depending largely upon the likelihood of encountering methane and upon the characteristics of the coal dust. Thus, in Utah mines, where methane is prevalent and the coal dust is especially explosive, open lights are not permitted in any coal mine. The regulation reads as follows:

> All men entering coal mines in Utah in which more than 5 men are employed on any one shift shall be equipped with electric battery lamps approved by the U. S. Bureau of Mines, and no flame lamps shall be permitted in the mine except for testing purposes. All lamps used for testing purposes shall bear the approval of the U. S. Bureau of Mines***. Mines employing 5 men or less on any one shift may be required to comply with the above regulations at the discretion of the Industrial Commission of Utah.

The regulations of thirteen States permit the use of open lights if methane is not present or if the methane concentration is kept below a prescribed maximum by suitable ventilation. Of these, seven (Maryland, New Mexico, Oklahoma, Tennessee, Virginia, West Virginia, and Wyoming) exclude open lights from the whole of the affected mine, while the other six (Colorado, Kentucky, Montana, Pennsylvania-Anthracite, Pennsylvania-Bituminous, and Washington) exclude only from the section affected. The rest of the coal-mining States do not exclude the use of open lights except from marked-off places, and then only until the gas accumulation has been cleared and the warning signs removed.

Power Lights

State regulations require that the top and bottom entrances to shafts be illuminated. This is almost always accomplished by fixed lights supplied with current from electric mains. All States permit the installation of such power lights in the yards or area around the shaft bottom and other places, such as stables, shops, and foreman's shanties; also along intake airways for lighting switches and safety stations and shelter holes.

Twenty States permit power lights anywhere at the discretion of the State Inspector, nine of them (Colorado, Maryland, New Mexico, Ohio, Oklahoma, Tennessee, Texas, Virginia, and West Virginia) by specific statement and the other eleven (Alabama, Arizona, Arkansas, Idaho, Illinois, Indiana, Iowa, Kansas, Michigan, Missouri, and North Dakota) by making no reference whatsoever to face lighting.

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Five States (Kentucky, Montana, Pennsylvania-anthracite, Washington, and Wyoming) prohibit power lights in gassy places; two States (Utah and Pennsylvania-bituminous) seem to permit such lighting if vaporproof fixtures are used and the lamps are not of the semiportable type.

None of the States prohibit the use of floodlights at working faces in non-gassy mines and most of them do not in gassy mines if certain requirements are met. However, virtually no floodlighting of faces in coal mines is done, as previously stated.

Special lighting is required by some States at track switches, rescue stations, fire extinguishers, and similar places, but the lighting of shelter holes is not generally required if they are adequately whitewashed or rock-dusted.

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